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L. O. HOWARD, Entomologist and Chief of Bureau.

# HOW TO CONTROL THE PEAR THRIPS.

BY

S. W. FOSTER AND P. R. JONES,

*Agents and Experts.*

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# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

## HOW TO CONTROL THE PEAR THRIPS.[a]

(*Euthrips pyri* Daniel.)

By S. W. FOSTER and P. R. JONES,
*Agents and Experts.*

### DISTRIBUTION.

The pear thrips (*Euthrips pyri* Daniel) (fig. 2) is at present confined to California and is very destructive throughout Santa Clara, Contra Costa, Solano, and Sacramento counties, with considerable areas infested in Alameda, Yolo, Napa, and Sonoma counties. (Fig. 1.) Reports of the presence of this species in other sections of California and in Oregon have been received, but each case was closely investigated and the insect in question found to be some other species. Bagnal[b] reports this insect in England; otherwise it is not known outside the State of California.

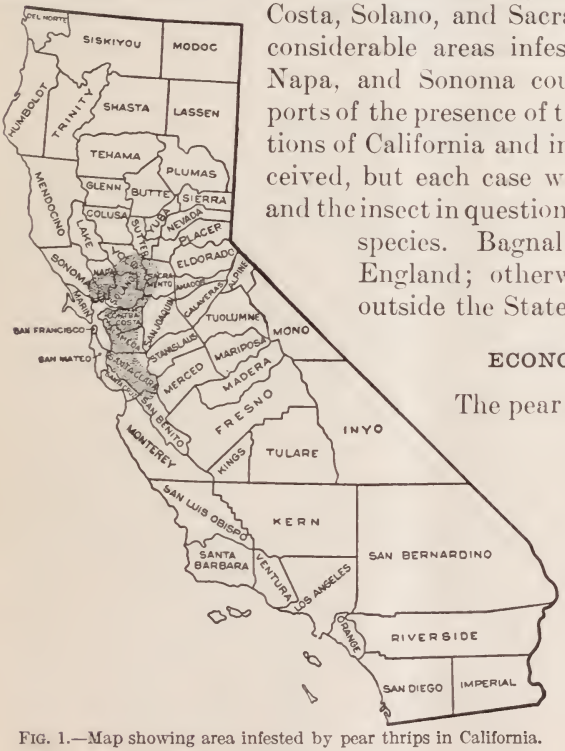



FIG. 1.—Map showing area infested by pear thrips in California. (Original.)

### ECONOMIC IMPORTANCE.

The pear thrips is at present the most important insect pest with which the growers of deciduous fruits in the counties mentioned have to contend. On account of the minute size of the insect, the rapidity of its spread over large areas, and the suddenness of attack in great numbers—completely blasting in a few

[a] The present paper is an abstract of a more comprehensive report on the life history and control of the pear thrips to be published later. The recommendations given are based on the results of experiments carried out in the principal centers of infestation since the fall of 1908 to and including the summer of 1910.

[b] Journal of Economic Biology, vol. 4, No. 2, 1909.

days all prospects for a crop of fruit—the control of this pest is a matter of considerable difficulty.

As the insect is each year extending its range of food plants, its capabilities for dissemination are correspondingly increased. There is no reason to believe that the insect will disappear in a few years, but it should be regarded as a permanent pest and at once realized that only the most careful attention each year to necessary control measures will make it possible to continue the profitable culture of deciduous fruit in infested orchards.

Conservative estimates place the damage caused by the pear thrips, in the Santa Clara Valley alone, during the years from 1904 to 1910 at nearly $2,000,000, while the loss for the entire State during this period probably exceeds $3,500,000. It is safe to say that the thrips in the absence of treatment would cause an average yearly loss to the State of over $1,000,000. Also each additional year an increase of several hundred thousand dollars is to be expected, due to the increase of area infested and the greater losses in the areas previously infested.

## CHARACTER OF INJURY.

Injury to the various fruit trees by this species is caused by the feeding of the adults on the developing buds and early blossoms; by the deposition of eggs into the fruit stems, leaf stems, and newly formed fruit, and by the feeding of the larvæ in the blossoms and on the young fruits and foliage. On pears the greater injury is produced by the adults, which often prevent the trees from blooming, while on prunes and cherries the larvæ frequently prevent a crop of fruit from setting after the trees have come into full bloom. Also, the deposition of eggs into the fruit stems of prunes and cherries so weakens the stems that much of the young fruit falls. The feeding injury is not produced by a biting or chewing process. By rasping the tender surfaces in the developing fruit buds and the young fruits with their hardened or chitinous mouthparts, the thrips rupture the skin, causing an exudation of sap which is often followed by more or less fermentation, especially before blooming. The feeding by larvæ on prunes after blooming causes the well-known thrips "scab," while most of the scarred and misshapen pears are caused by the work of the adults.

## LIFE HISTORY.

*Adults.*—The adults (fig. 2) or winged form of the thrips first appear on the trees about the middle of February and emergence

from the ground continues till early April, maximum emergence, however, occurring in late February and early March. Examina-

FIG. 2.—The pear thrips (*Euthrips pyri*): Adult, greatly enlarged. (Original.)

tion of the tables of emergence records (Tables I to V) will show the dates of emergence for 1909–10:

TABLE I.—*Total daily emergence of thrips from all cages at laboratory, San Jose, Cal., 1909 and 1910.*

| Date. | Number thrips emerging in 1909. | Number thrips emerging in 1910. | Date. | Number thrips emerging in 1909. | Number thrips emerging in 1910. |
|---|---|---|---|---|---|
| Feb. 9 | 0 | 25 | Mar. 8 | 219 | 275 |
| 10 | 0 | 18 | 9 | 776 | 144 |
| 11 | 0 | 16 | 10 | 497 | 100 |
| 12 | 0 | 16 | 11 | 498 | 73 |
| 13 | 0 | 4 | 12 | 338 | 179 |
| 14 | 0 | 88 | 13 | 313 | 45 |
| 15 | 18 | 22 | 14 | 248 | 20 |
| 16 | 0 | 27 | 15 | 279 | 7 |
| 17 | 52 | 34 | 16 | 259 | 4 |
| 18 | 192 | 33 | 17 | 152 | 20 |
| 19 | 192 | 14 | 18 | 42 | 7 |
| 20 | 169 | 23 | 19 | 61 | 2 |
| 21 | 75 | 62 | 20 | 28 | 2 |
| 22 | 119 | 129 | 21 | 2 | ..... |
| 23 | 135 | 375 | 22 | 6 | ..... |
| 24 | 552 | 272 | 23 | 13 | ..... |
| 25 | 459 | 297 | 24 | 3 | ..... |
| 26 | 444 | 455 | 25 | 2 | ..... |
| 27 | 414 | 574 | 26 | 3 | ..... |
| 28 | 781 | 657 | 27 | 7 | ..... |
| Mar. 1 | 781 | 1,975 | 28 | 7 | ..... |
| 2 | 535 | 3,592 | 29 | 0 | ..... |
| 3 | 1,299 | 3,011 | 30 | 2 | ..... |
| 4 | 714 | 4,217 | 31 | 0 | ..... |
| 5 | 508 | 1,402 | Apr. 1 | 3 | ..... |
| 6 | 362 | 1,595 | 2 | 0 | ..... |
| 7 | 438 | 539 | 3 | 1 | ..... |

EMERGENCE RECORD FOR CONTRA COSTA COUNTY.

TABLE II.—*Emergence of thrips from cages placed in ground under trees in pear and prune orchards, Walnut Creek, Cal.*

| 1909. | | 1910. | |
|---|---|---|---|
| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
| Feb. 13 | 0 | Feb. 21 | 1 |
| 16 | 20 | 23 | 4 |
| 19 | 37 | 25 | 23 |
| 22 | 30 | 27 | 36 |
| 26 | 110 | Mar. 1 | 56 |
| Mar. 2 | 615 | 3 | 237 |
| 5 | 679 | 5 | 1,170 |
| 10 | 752 | 7 | 2,110 |
| 12 | 273 | 9 | 892 |
| 16 | 65 | 11 | 1,773 |
| 20 | 33 | 13 | 557 |
| 22 | 4 | 15 | 198 |
| 27 | 11 | 17 | 71 |
| | | 19 | 3 |
| | | 21 | 6 |
| | | 27 | 5 |

TABLE III.—*Emergence of thrips from soil samples taken from orchard in November and December and kept in cages at laboratory, Walnut Creek, Cal.*

| 1909. | | 1910. | |
|---|---|---|---|
| Date. | Number of thrips out. | Date. | Number of thrips out. |
| Feb. 12 | 3 | Feb. 18 | 11 |
| 15 | 42 | 20 | 16 |
| 16 | 56 | 22 | 0 |
| 17 | 38 | 24 | 12 |
| 18 | 56 | 26 | 30 |
| 20 | 89 | 28 | 75 |
| 23 | 125 | Mar. 2 | 377 |
| 25 | 185 | 4 | 918 |
| 27 | 246 | 6 | 937 |
| Mar. 1 | 196 | 8 | 165 |
| 4 | 237 | 10 | 114 |
| 7 | 51 | 12 | 47 |
| 10 | 52 | 14 | 0 |
| 14 | 13 | 16 | 4 |
| 19 | 0 | | |
| 22 | 0 | | |

EMERGENCE RECORD FOR SOLANO COUNTY, 1910.

TABLE IV.—*Emergence of thrips from cages placed in ground under trees in orchards, Suisun, Cal.*

| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
|---|---|---|---|
| Feb. 17 | 3 | Feb. 27 | 20 |
| 19 | 0 | Mar. 1 | 47 |
| 21 | 0 | 3 | 121 |
| 23 | 0 | 10 | 484 |
| 25 | 1 | 16 | 1 |

TABLE V.—*Emergence of thrips from samples taken from orchard in November and December and kept in cages at laboratory, Suisun, Cal.*

| Date. | Number of thrips emerging. | Date. | Number of thrips emerging. |
|---|---|---|---|
| Feb. 16 | 1 | 26 | 11 |
| 17 | 3 | 27 | 14 |
| 18 | 2 | 28 | 41 |
| 19 | 6 | Mar. 1 | 105 |
| 20 | 1 | 2 | 247 |
| 21 | 1 | 3 | 243 |
| 22 | 4 | 7 | 612 |
| 23 | 2 | 12 | 357 |
| 24 | 5 | 16 | 82 |
| 25 | 11 | 19 | 8 |

By the time the fruit buds have swollen sufficiently to separate the bud scales slightly at the tip the adults force their way within, feeding upon the tenderest portions inside the buds. When the thrips are present in sufficient numbers the buds are completely destroyed and the trees fail entirely to bloom.

FIG. 3.—The pear thrips: Eggs, highly magnified. (Original.)

*Eggs.*—As soon as the first leaf surfaces or fruit stems are exposed egg laying usually begins, depending somewhat on the variety of fruit attacked. The first eggs are deposited the last days of February and oviposition continues till near the middle of April, being at its maximum, however, from the 10th of March to the 1st of April. Most of the eggs (fig. 3) are deposited just under the epidermis in the fruit stems, young fruit, and leaf stems. The eggs require from five to seventeen days to hatch, the average time being about eight days.

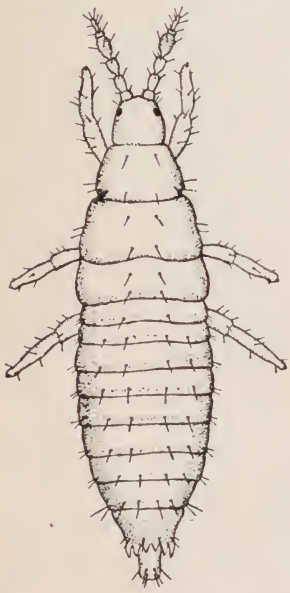


FIG. 4.—The pear thrips: Larva, greatly enlarged. (Original.)

*Larvæ.*—By the time the trees are breaking into full bloom the adults have done most of the damage caused by their feeding, and oviposition is at its height. Many of the earlier appearing adults are dying off and larvæ (fig. 4) are beginning to appear in numbers. The very first larvæ can usually be found about March 20, and are in maximum numbers on the trees, feeding on the small fruit and young foliage, from the first to middle of April. Reaching their full development, the larvæ drop from the trees, of their accord or with falling calyces, or are blown by wind or knocked off by rain. After the

middle of April the number on the trees diminishes rapidly, and by the last of April all the larvæ are off the trees and in the ground. Here they work down into the first 3 or 4 inches of hard soil below the loose surface mulch and construct a tiny cell, where they remain until the following spring.

*Pupæ.*—The larvæ mostly remain as such in these cells till September, when pupation begins, pupæ (fig. 5) being most abundant during October and November. Many adults can be found in the ground in December, and by the 1st of January practically all the thrips are in the adult stage and apparently ready to emerge and go into the trees whenever conditions are right. Broadly speaking, the thrips spend two months of the year in the adult, egg, and larval condition on the trees and the other ten months of the year as larvæ, pupæ, and adults in the ground.

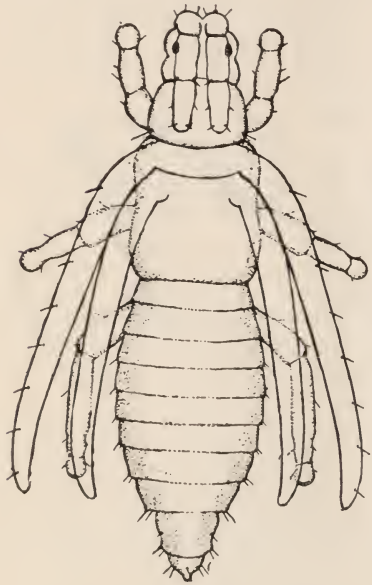


FIG. 5.—The pear thrips: Pupa, greatly enlarged. (Original.)

## CONTROL MEASURES.

The pear thrips is in some respects an unusual insect in that it remains in a dormant or semidormant condition for about ten months of the year. Although on the trees for only two months out of the twelve, it is able in this short time, in the absence of treatment, to completely destroy all prospects of a crop of fruit, in many cases within a very few days. The trees are attacked at the period of bud swelling and blossoming, when they are most susceptible to injury. These minute insects come literally in swarms, and may, if left alone, completely destroy all of the fruit buds of an orchard in four or five days. Many cases have been known where a delay of four or five days in spraying resulted in loss of the entire crop of fruit, and in some cases half of all the buds were killed in three days after the thrips appeared on the trees in great numbers. In view of this condition it is very evident that any means of control must be very thorough and done in the most exacting manner at the proper time.

## EXPERIMENTS IN THRIPS CONTROL.

Many experiments with soil fumigants, fertilizers, and irrigation were made with the hope of killing the thrips while in the ground,

but all of them have proved to be absolutely of no avail, or at most impractical and expensive. In most cases the general vigor and health of the trees were improved by early fall irrigation and by the application of fertilizers.

### CULTIVATION.

Thorough plowing in the fall in prune orchards planted on gravelly and sandy soils gave very helpful results. Success by deep plowing, cross plowing, and harrowing in October and November was fairly general in all experiments tried in Santa Clara County in the fall of 1908 and 1909. This manner of cultivation, when carried out to a depth of from 7 to 9 inches, resulted in killing from 60 to 80 per cent of the thrips present in the soil, but was not a sufficient control, as enough thrips escaped to cause great injury to the buds the following spring.

### SPRAYING.

A long list of insecticides was tried out in spraying experiments, both in the laboratory and by spraying the trees in the spring. All poison sprays had to be abandoned because of the inability to poison the thrips, as both adults and larvæ do not feed in a way to be subject to poisoning. Sticky sprays were difficult to apply and proved ineffective, as they do not retain this quality long and the thrips seem capable of moving around on almost any kind of surface. Dust sprays and preventive sprays had to be abandoned because the dust sprays failed to kill and the rapid swelling of buds and continued appearance of new surface area gave the thrips plenty of feeding ground and exposed places of entrance into the buds. Success with contact sprays seemed more apparent; of these, various caustic sprays, such as caustic-soda and carbolic-acid solutions, gave excellent results in killing the thrips, but were, as a rule, unsafe because of injury to the trees.

Solutions of tobacco extract were very promising, and when used at sufficient strengths killed all the thrips actually reached, but they lacked sufficient penetrating quality to enter the swelling buds, a condition absolutely necessary, especially on pears, as most of the injury is done inside the cluster buds. Mechanical mixtures of various mineral oils and animal-oil soaps were tried and abandoned because of the difficulty of keeping them thoroughly mixed and the resulting injury to the trees caused by free oil separating out. Fish-oil soap emulsions with these various oils gave better results, the raw distillates running from 30° to 40° Baumé being decidedly preferable over either the kerosenes or the heavy crude oils.

A distillate-oil emulsion made according to directions (see pages 8–10) gave better penetration into the swelling pear buds than any other material which has been tried. There was one drawback, however; when this emulsion was used in sufficient strengths to kill all the

thrips present or even a large percentage of them, there was considerable oil injury to the buds. It was found that the weaker emulsions of from 3 to 6 per cent strengths had all the desired penetrating qualities and with little or no injurious effect upon the trees. As the nicotine solutions killed all the thrips present and gave no spray injury this led to a combination of the two in Contra Costa County in the spring of 1909 with most satisfactory results.

A tobacco extract containing 2¾ per cent nicotine, diluted at the rate of 1 to 60 in a 6 per cent distillate-oil emulsion, killed all the thrips touched and penetrated well into the pear cluster buds. The pubescent covering of the individual buds in the cluster, being resistant to water, seemed to act on the dilution in distillate-oil emulsion in much the same manner as the wick upon oil in a lamp. Various other combinations of nicotine solutions with "lime and sulphur solutions" and "lysol solutions" and "soap solutions" were tried extensively, but none proved to be as effective and at the same time as practical as the combination of distillate-oil emulsion and the nicotine solutions.

### DISTILLATE-OIL EMULSION.

*Homemade preparation.*—Because of its cheapness and greater efficiency as a penetrating spray, and therefore a more satisfactory killing agent, growers are strongly advised to make their own emulsions and, preferably, the soap, although the latter can usually be depended on if bought from reliable dealers.

*Directions for making.*—To make soap use this formula or some multiple of same:

| | |
|---|---|
| Water | 6 gallons. |
| Lye (98 per cent) | 2 pounds. |
| Fish oil | 1½ gallons. |

Put the water in a caldron or boiler and add the lye. When the lye is thoroughly dissolved and the water boiling, pour in the fish oil, stirring in the meantime, and boil slowly for two hours. When the soap has boiled sufficiently it should give a ropy effect when stirred and brought up upon the ladle. This formula gives about 40 pounds of moderately firm soap.

Growers are cautioned to buy only genuine fish oil and not a fish-oil compound or a mixture of fish oils and vegetable oils. Herein lies part of the secret of the penetrating efficiency of the distillate emulsions made by using animal-oil soap as the emulsifier. The cost of the soap is $0.0165 per pound made from fish oil at 35 cents a gallon.

The distillate-oil stock emulsion should be made as follows:

Formula:[a]

| | |
|---|---|
| Hot water | 12 gallons. |
| Fish-oil or whale-oil soap | 30 pounds. |
| Distillate oil (raw) 30° to 34° Baumé | 20 gallons. |

[a] For a spray tank of 200 gallons capacity, five times this formula can be made at one time.

Have the water boiling hot when put into the spray tank and add the soap immediately while the agitator is running at a good speed. When the soap is all thoroughly dissolved, pour in the oil slowly, keeping the mixture well agitated while the oil is going into the tank. When all the oil is in and well mixed, pump out through the nozzles at good pressure (not less than 175 pounds) into storage tanks.

No one should attempt to make this stock emulsion without a power spraying machine, as thorough agitation and high pressure are important requisites. Also, care should be used in having measurements reasonably exact, the water boiling hot, and soap thoroughly dissolved, before any oil is put in. This stock emulsion contains approximately 55 per cent oil, and to make a 3 per cent emulsion use 5½ gallons of this stock in each 100-gallon tank. To dilute, first put the stock emulsion in spray tank (have the agitator going), and then add the water, keeping the agitator running all the time. This is important with the commercial preparations as well as with the home-made emulsions. For the combination sprays of oil emulsions and nicotine solutions, the nicotine should be added last, that is, after the oil emulsion has been diluted to the desired strength. These solutions should not be mixed together without first diluting one of them.

This concentrated emulsion will cost the grower about 5 cents per gallon, as most of the various distillates used for spraying cost from 5 to 10 cents a gallon in drum lots.

In the spraying season of 1910 many growers of Contra Costa County experienced great difficulty in making emulsions that would remain emulsified when diluted. Part of this trouble was due to the varying degrees of hardness in the water, but more to the composition of the oil, especially where the treated oils and in some cases ordinary stove distillates were used. Even after these treated oils were emulsified by changing the amount of soap used and treating the water to "soften" it, the result was not satisfactory, as the diluted emulsion from this lacked the essential penetrating quality and had a tendency to collect in large drops rather than to spread out in a thin film.

Experiments conducted thus far indicate that success is more uniformly obtained by using an untreated raw distillate 32° to 34° Baumé with comparatively high flashing point. Some of the treated oils have given good results, but as a whole the untreated raw, straight distillates, comparatively free from naphtha and with a high flashing point, have given far better and more general satisfaction.

Some of the oil companies, particularly in the Bakersfield and Coalinga districts, put out raw short-cut distillates—that is, the first distillate after the naphtha, gasolines, etc., have been removed. This kind of oil when running 32° to 34° Baumé should under all circumstances be given preference. The ordinary stove distillates have not, as a rule, given as good satisfaction, possibly because they

contain too much of the light gaseous oils, which lower the flashing point.

There are several commercial preparations of oil emulsions and miscible oils on the market, but these have not given as satisfactory results against the adult thrips as the homemade preparation, especially on pears, on account of the noticeable lack of penetration into the cluster buds. Besides, all of these commercial preparations are far more expensive. Allowing 25 cents per hour for labor in making the soap and the concentrated homemade emulsion, the commercial preparations cost the grower from 2 to 5 times more than the more efficient homemade preparation.

## COMMERCIAL RESULTS.

During the season of 1909–10 many large-scale experiments and demonstrations were carried out in pear, prune, and cherry orchards to determine more conclusively the effectiveness of this combined spray and to put the treatment on a commercial basis; also, that growers might see for themselves the results of the work and know the monetary gain possible by such control measures as are recommended. The commercial results from some of these experiments are given below:

### PRUNES, SANTA CLARA COUNTY.

The 16-acre prune orchard belonging to Mr. P. Landon, situated in the Willows district, near San Jose, Cal., consists of some of the largest and finest prune trees in the valley. The trees, which are about 25 years old, are planted 20 feet apart and the branches now overlap between the rows. The orchard has very heavy sandy loam and has been well cultivated and usually irrigated twice each year. Thrips became injurious in the year 1906, increasing greatly in 1907, and causing much injury over the entire orchard, so that instead of a normal crop of a hundred or more tons of green (undried) prunes the entire 16 acres produced only 18 tons of green fruit. Injury by the thrips was worse in 1908, the yield that year being only 10 tons of green prunes.

#### Demonstration for 1909.

In the fall of 1908, under direction of the Bureau of Entomology, Mr. Landon plowed and cross plowed this orchard to a depth of 9 inches, with thorough harrowing after each plowing. Thrips were very abundant in the soil, there being sometimes as many as 3,000 to the square foot.

The following table, giving the emergence of adults in spring from samples of soil taken before and after plowing, shows that approximately 70 per cent of the thrips were killed by cultivation:

TABLE VI.—*Number of adult thrips emerging from cages containing samples of soil taken before and after plowing—Landon prune orchard, 1908–9.*

| Plowed and cross plowed. | | | | Before plowing. | |
|---|---|---|---|---|---|
| Cage I. | Cage II. | Cage III. | Cage IV. | Cage V. | Cage VI. |
| 475 | 389 | 607 | 115 | 1,175 | 1,474 |

| | |
|---|---|
| Average number of thrips per cage before plowing | 1,364 |
| Average number of thrips per cage after plowing and cross plowing | 396 |
| Percentage living in treated areas as against the number of thrips living in untreated ground.....per cent.. | 30 |
| Approximate percentage killed .....do.... | 70 |

In the spring of 1909, 5⅓ acres of this 16-acre orchard were sprayed three times; twice before blooming, for adults, the first application March 8 and 9, just as cluster buds were spreading, and the second

FIG. 6.—Power sprayer at work in Landon prune orchard, 1909. (Original.)

application March 16 and 17, just as the white tips of the petals were beginning to show. The third application or larval treatment was put on April 11 and 12, after most of the petals had fallen. For all sprayings a gasoline-power outfit, with tower platform and three leads of hose, as shown in figure 6, was used, two men spraying from the ground and one from the tower to cover the tops of the trees. The material used was the recommended 3 per cent homemade distillate-

oil emulsion with commercial tobacco extract No. 1, added at the rate of 1–60, and the cost of the three applications was $157.38, the labor required in spraying being three men at $2 per day and one team at $2.50 per day, making a total of $8.50 per day, or a total of $51 for the six days; gasoline for the engine cost $2.40; plowing and cross plowing the previous fall, $26.65, making a total cost of $237.45 for the combined treatment of plowing and spraying the 5⅓ acres, or $44.54 per acre, an average of $0.449 per tree.

The yield from this plat was 45 tons of green prunes, making an average yield of 8.44 tons per acre, or 155.17 pounds per tree. The prunes when dried averaged 54 to the pound, giving a commercial value for the plat of $1,710, or a value of $320.82 per acre, or an average of $2.948 per tree, as the prunes were sold on a 2½-cent basis for dried prunes averaging 80 to a pound.

*Plat II.*—The rest of the orchard, comprising 10⅔ acres, and which only had the plowing and cross plowing in the fall of 1908, at the cost

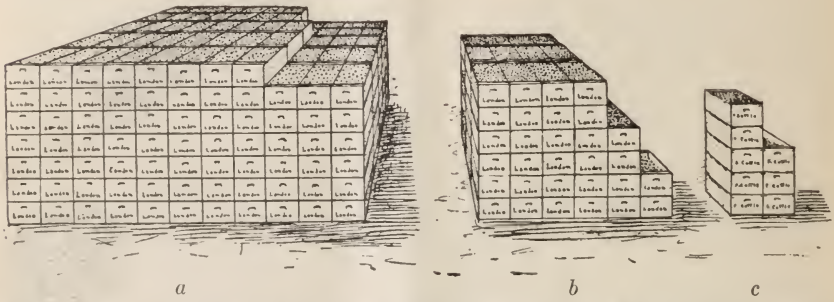



FIG. 7.—Diagram showing yield in green prunes per acre upon the sprayed, plowed, and check blocks, Landon prune orchard, 1909: *a*, Sprayed and plowed, 367.93 boxes, value $320.82 per acre; *b*, plowed block, 85.65 boxes, value $74.85 per acre; *c*, check block, 7 boxes, value $6.65 per acre. (Original.)

of $5 per acre, or $0.046 per tree, yielded 21 tons of green prunes, or an average of 1.97 tons per acre, or 36.45 pounds per tree, giving a commercial value of the plat as $798, or a value of $74.85 per acre, averaging $0.692 per tree.

*Plat III, check.*—This plat, embracing 5 acres of the prune orchard belonging to Mr. F. Cottle, and immediately adjoining the Landon orchard and of the same kind of soil and with similar trees in regard to size and previous care, received no treatment for thrips. The total yield was 1,750 pounds of green prunes, or an average yield of 350 pounds per acre, or 3.24 pounds per tree, representing a commercial value of $33.25 for the plat, or an average of $6.65 per acre or $0.06 per tree. The yield and value per acre upon the three plats is shown diagrammatically in figure 7.

The average gain per acre upon Plat I was obtained after adding the total cost of treatment per acre to the value of the crop per acre from the check plat, and subtracting that amount from the value of

the yield per acre upon Plat I. This gave a net gain of $269.53 per acre as returns upon an investment of $44.54, or a gain of about 600 per cent. The gain upon this plat due to the spraying alone was $199.88 per acre, or $1.85 per tree.

Plat II, which received only the plowing and cross plowing, gave, after adding the cost of the treatment to the yield per acre upon the check plat and subtracting the total from the yield per acre upon Plat II, a gain of $63.20 per acre for an investment of $5, or about 1,200 per cent on the investment.

Owing to the lateness of the third application on Plat I, the larvæ caused considerable scabbing on the fruit, and the difference in quality of the fruit from Plat I and Plat II was not as great as would have been the case had the larval application been applied a few days earlier.

### Results, 1910.

During the fall of 1909 part of the orchard was irrigated and the entire 16 acres were plowed to a depth of 8 inches in November. One small block was cross plowed. The entire orchard was harrowed several times after the plowing.

### Plowing Results.

Soil samples were taken in similar cages as in the previous year and yielded the following results:

| Cage No. | Treatment. | Total number thrips. | Per cent killed. |
|---|---|---|---|
| II | Before plowing | 2,813 | 0 |
| II-a | Plowed once | 353 | 87 |
| IV | Before plowing | 3,379 | 0 |
| IV-a | Plowed once | 1,306 | 61 |
| I | Before plowing | 2,731 | 0 |
| I-a | Plowing and cross-plowing | 27 | 98 |

The average percentage of thrips killed by one plowing was 71 per cent and the average number killed by plowing and cross plowing 98 per cent.

No spraying was done in 1910, except a few trees for other experiments.

*Results.*—All of the trees on the 16 acres came into heavy bloom, but only the 580 trees of Plat I and one block of about 80 trees which was sprayed for larvæ in 1909 set a heavy crop, as many thrips were present in the rest of the orchard. The trees sprayed in 1909 were stronger, and so many of the thrips had been killed by the treatment that the accumulative results showed almost as great a difference in the crop yield for 1910 as was the case in 1909, when the spraying was actually done.

The prunes averaged 57 to the pound, and computations made on the basis of 5 cents for prunes running 80 to the pound. The different yields and values were as follows:

*Plat I—Demonstration block of 1909, consisting of 580 trees.*—This block yielded 35 tons 212 pounds of green prunes, worth $2,109.87 for 580 trees, or $3.63 per tree or $392.04 an acre.

*Plat II—Sprayed for larvæ in 1909, 80 trees.*—This block yielded 2 tons 676 pounds of green prunes, worth $140.51 for 80 trees, or $1.99 per tree or $214.92 per acre. (This was part of Plat II in 1909.)

*Plat III—Remainder of orchard, consisting of 10 acres, not sprayed in 1909.*—This block yielded 7½ tons of green prunes worth $450.75 for 1,080 trees or 10 acres, making $0.417 a tree or $45.075 an acre.

An examination of the above statement of yields and values shows that great headway can be made the first year in eliminating the thrips injury from an orchard by thorough spraying and that a considerable benefit extends into the second year.

### Demonstrations for 1910.

The 6½-acre prune orchard belonging to Mr. H. Curry was plowed and cross-plowed in November, 1909, to a depth of 11 inches and harrowed after each plowing. The block was then sown to barley for a cover crop which made a good growth and was at spraying time nearly 3 feet high.

Examination of two samples of soil 17 by 17 inches square, taken before plowing, and two of the same size taken after plowing, showed that approximately 61 per cent of the thrips were killed.

*Plat A.*—In addition to the fall plowing, this block of 300 trees received three applications of commercial tobacco extract No. 1 combined at the rate of 1 to 66 with 3 per cent homemade distillate-oil emulsion. The first spraying was applied March 7, just as the cluster buds were spreading. The second for adult thrips was made March 17, as the tips of the petals were showing. The third application, which was for the larvæ, was made April 6, after most of the petals had fallen. In all of the spraying an effort was made to direct the spray into the end of each bud and to drench the trees thoroughly.

*Plat B.*—This plat, consisting of 98 trees, received the cultivation, but no spraying.

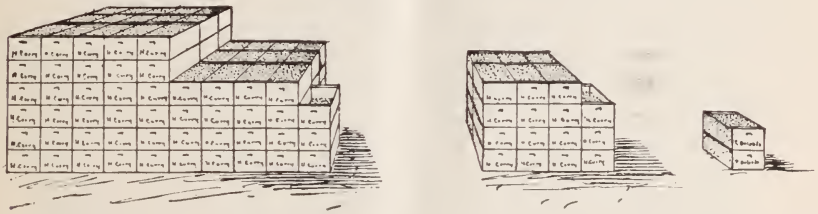
*Results.*—The first application was made too late to obtain best results, and a large number of buds was so far advanced that it was difficult to reach all of the thrips. A series of counts showed that all of the exposed thrips were killed and about 30 per cent of those within the buds. The second application killed practically all the thrips left on the trees (over 90 per cent), as the bud clusters were spreading at this time. A fair portion of the blossoms set fruit on the

sprayed block and some on the plowed block, but the fruit on the latter continued to drop until picking time. The yield upon the various plats is shown diagrammatically in figure 8, and was as follows:

Plat A yielded 16,254 pounds of green prunes, or 8,127 pounds of dried prunes, from the 300 trees. This made an average yield of 5,849.92 pounds of green prunes per acre, or 54.166 pounds per tree.

Plat B yielded 1,032 pounds of green prunes or 516 pounds of dried prunes from the 98 trees, or an average of 1,138.32 pounds per acre, or 10.54 pounds of green prunes per tree.

Plat C, consisting of 10 acres, was left untreated to serve as a check for comparison, and yielded 860 pounds of green prunes, or 430 pounds of dried prunes, for the 1,080 trees. This gives an average yield of 86.4 pounds per acre, or 0.8 pound of green prunes per tree.



*a* *b* *c*

FIG. 8.—Diagram showing yield per acre in green prunes, Curry orchard, 1910: *a*, Sprayed and plowed, 136.08 boxes, value $190.08 per acre; *b*, plowed block, 26.46 boxes, value $34.02 per acre; *c*, check block, 2 boxes, value $2.59 per acre. (Original.)

*Scabbiness.*—An examination and count was made of all the fruit from 5 trees on the sprayed block and from 5 trees in the unsprayed block, giving the following results:

| Plat. | Total number prunes. | Number clean. | Number scabby. | Per cent free from scab. |
|---|---|---|---|---|
| Sprayed block | 10,139 | 9,831 | 308 | 96 |
| Unsprayed block | 826 | 0 | 826 | 0 |

It will be seen from the above table that the sprayed fruit was practically free from scab (the 4 per cent that was scabby being only very slightly marked), while the unsprayed fruit was all badly scabbed.

*Size of fruit.*—Comparisons of the sprayed and unsprayed fruit when dried showed the former to average 50 prunes to the pound and the unsprayed 60 to the pound, making a difference of $10 a ton, which would pay nearly half the cost of the spraying.

*Value of the crop.*—As all of the values of the prune yields for 1910 have been figured on a 5-cent basis for prunes averaging 80 to the pound dried, this basis is here employed, although the crop was sold for more than the above quotation and premiums were given for the large size and quality of the fruit.

Plat A, which produced 16,254 pounds of green prunes from 300 trees, gave a crop value of $528.255, or $1.7608 a tree, or $190.08 an acre.

Plat B, which yielded 1,032 pounds of green prunes from 98 trees, gave a crop value of $30.96, or $0.315 a tree, or $34.02 an acre.

Plat C, which yielded 860 pounds of green prunes from 1,080 trees, gave a crop value of $25.80, or $0.024 a tree, or $2.592 an acre.

*Cost of spraying.*—As 3,800 gallons of diluted spray material were used for all three sprayings upon Plat A, the total cost at $0.01625 per diluted gallon would be $61.75. The labor and gasoline cost 2 cents a tree, each application, for the 300 trees, or a total of $18. The total cost of the spraying was $79.75, or $0.265 a tree, or $28.78 an acre for the three applications.

*Gain due to spraying.*—The gain due to the spraying would be obtained by adding the value of the crop per tree on Plat B to the cost of the spraying and subtracting the product from the value of the crop per tree of Plat A. This gives a gain due to the spraying of $1.18 per tree, or $127.44 an acre.

### Other Demonstrations.

In cooperation with or working under the advice of the Bureau of Entomology, several fruit growers in Santa Clara, Contra Costa, Solano, and Sacramento counties during 1910 gave thorough treatment to portions of their orchards and left similarly infested areas untreated without any protection from thrips injury. Many of these demonstrations were highly successful, but for lack of space only two of these are recorded herein in some detail. These results show very conclusively what can be done by the individual growers if the right material is properly applied in time to kill the thrips before the buds have been destroyed, and that the treatment will increase the yield and value of the crop, frequently paying several hundred per cent on the investment.

### Pears, Contra Costa County.

An orchard consisting of about 5½ acres of Bartlett pears belonging to John Swett & Sons, in the Alhambra Valley, near Martinez, Cal., had been badly damaged by thrips for three years, causing almost total failure of crop.

In the spring of 1910 Mr. Frank T. Swett had 550 of the trees sprayed twice for adults, and a portion of these received a third application or larval treatment. All spraying consisted of the recommended material (commercial tobacco extract No. 1 diluted 1 part to 66 in 3 per cent homemade distillate-oil emulsion) put on the trees with good pressure, using gasoline-power outfit with 8-foot tower, thus enabling one man to cover thoroughly the tops of the trees and

drench all buds pointing upward which could not be properly sprayed by the men on the ground.

Four trees in one side of this orchard, same variety, same age and size, and all other conditions the same, were left unsprayed.

*Results.*—Without a single exception all of the 550 sprayed trees came uniformly into full bloom, while the trees left unsprayed showed only very few scattering blossoms and these badly injured. Figure 9

FIG. 9.—Swett pear orchard at time of blooming. Sprayed trees. (After Swett.)

shows the condition of a sprayed tree at blossoming time. The 550 sprayed trees gave a yield of 1,700 boxes of No. 1 pears and 150 boxes of No. 2 pears. The No. 1 pears, at an average net price of 80 cents per box, gives $1,360, and the 150 boxes of No. 2 pears, at 50 cents per box, gives $75, making a total of $1,435, the value of the crop from 550 sprayed trees, or practically $2.60 per tree.

Figure 10 shows an unsprayed tree at blossoming time. The unsprayed trees gave a yield of less than one-fourth box per tree, all of which was scarred, misshapen, and unmerchantable; but counting them as No. 2 pears, at 50 cents per box, gives a return of about 12½ cents per tree.

According to Mr. Swett, the spraying, including material, labor, and all expenses connected with the operation, cost less than 25 cents

FIG. 10.—Swett pear orchard at time of blooming. Unsprayed trees, sprayed portion of orchard in background. (After Swett.)

per tree for the 550 trees. This, plus the value of the crop (12½ cents) from the check trees, gives 37½ cents. Subtracting this from the $2.60, value of the crop per tree in the sprayed block, leaves a net gain of $2.125 per tree, or approximately $225 per acre, or a return of over 900 per cent on the investment.

In the letter giving the results upon which these itemized figures are based, Mr. Swett continues:

> The results from spraying on prune trees were very marked. Owing to cross limbs we could not use the tower in spraying the prune orchard. The crop was protected only up to the distance from the ground that could be reached by the spray rods. We wet the tops of the trees as best we could, but could not drive the spray into the bud and flower clusters directly from the nozzles. Anyone can tell where the rods reached, for above the line there is no crop, and below that line the limbs mostly have to be propped.

CHERRIES, SACRAMENTO COUNTY.

A good demonstration showing the possibility of control and the commercial advantage by spraying cherries was given by Mr. T. W. Dean, near Courtland, Cal. Mr. Dean has about 1½ acres or 180 trees in bearing, which were sprayed upon an average four times in the spring of 1910 (some of the trees sprayed five times and the remainder only three times). The cost of the spraying was approximately $90, or 50 cents per tree. Mr. Dean shipped 1,362 boxes of cherries from the 180 trees, or 7.56 boxes per tree, which, at a net value of $1.196 per box, gives a return of $1,619.95, or $8.99 per tree.

Sixty-five trees belonging to Mr. I. G. Doty and immediately adjoining the above orchard were not sprayed. The 65 trees gave a yield of 43 boxes, averaging practically two-thirds of a box per tree, or a cash value of $0.798 per tree. Adding this to the cost of spraying, 50 cents per tree, gives $1.30 as the amount to be deducted from the value of the crop per tree in the sprayed orchard. The difference is $7.49 per tree, or approximately $898.80 per acre, the net gain due to spraying paying over 1,400 per cent on the investment.

## RECOMMENDATIONS.

Spraying is by far the most satisfactory means for controlling the pear thrips on all classes of deciduous fruit trees in California. However, to spray successfully involves an entirely different conception of the operation than as ordinarily practiced against other orchard insects. Only the most efficient spray materials should be used, namely, the combination of distillate-oil emulsion and tobacco extract or distillate-oil emulsion and nicotine solutions. The spraying must be thoroughly done and put on the trees when the thrips appear in numbers, not waiting till many buds have been destroyed. It is strongly advised to use power machines, and growers are urged to use them for all the spraying, and to have a tower platform elevated over the tank so that one man can thoroughly drench the tops of the trees. Figures 6 and 11 show two good types of power outfits at work. It is absolutely necessary to use high pressure—from 150 to 200 pounds—and only angle nozzles should be employed, and these

must be held close to the bud clusters to *force the spray directly into the ends of the buds.* This is absolutely necessary to secure good penetration and get satisfactory results. Plenty of material—3 to 5 gallons per tree for pears, depending on the size of the tree—should be used; more liquid is required for large prune trees; large cherry trees may require 7 to 8 gallons per tree for satisfactory results. Only two rows should be sprayed at a time, using three men, one on the tower to spray the tops of the trees, thus reaching all buds pointing upward, and two men on the ground (one to each row) to spray the lower buds and those pointing downward or laterally.

FIG. 11.—Power outfit ready for use in spraying experiments in pear orchards, Contra Costa County, Cal., 1910. (Original.)

## TIMING THE APPLICATIONS.

The spraying must be done on time, and for best results all the trees should be treated within a few days. During the season of 1910 more of the failure to get satisfactory results was due to lateness of application than to any other one cause. Thrips were in the trees and in great numbers before many of the growers purchased their spraying supplies, and in many cases half the buds were entirely destroyed and the others badly injured before the trees had been given even the first application. The grower should have everything in readiness, all materials on hand, concentrated emulsion made up, and spray machinery in perfect working order by the first of March and have all other orchard work in such shape that when the thrips appear in numbers

the spraying may be done at once and before the buds have been seriously injured by the feeding of the adults. The grower should have enough spray machines to cover the orchard quickly. At least one good power outfit is necessary for every 30 acres of orchard.

### SCHEDULE OF APPLICATIONS.

In badly infested orchards three applications are necessary the first year for controlling the pear thrips. Two of these sprayings should be directed against the adults and one against the larvæ, and to obtain satisfactory results must be timed properly.

*First application.*—The first spraying should come as soon as the thrips can be found on the trees in numbers. This will usually be the first two or three days of March, just as the earliest buds are separating slightly at the tips. In figures 12, 13, and 14 are shown photographs of the more advanced buds of Bartlett pear, Imperial and French prunes, and Black Tartarian cherry, which were taken at time of first application.

FIG. 12.—Bartlett pear cluster buds showing stage of earliest buds at time of first spraying against thrips. (Original.)

*Second application.*—The second spraying, which is also for adults, should come from four to ten days after the first, depending somewhat on variety of fruit, stage of bud development, and rapidity of emergence of thrips from the ground. On pears this will usually be just as the earliest cluster buds are spreading, and on prunes and cherries when the tips of the petals first begin to show.

Both of these applications are important and necessary to insure the production of a good crop of uninjured blossoms. The nozzles should be held close to the bud clusters and the spray directed into the ends of the buds. This makes it necessary that the spraying be done mostly from above.

*Third application.*—The third spraying is for larvæ and properly comes just as most of the petals are falling from the trees, depending somewhat upon the variety of fruit. In any case the small, white, active larvæ can be easily seen, and when they first become abundant spraying should be done. In this larval spraying on cherries and prunes where there is a large amount of leaf surface exposed, the

spray should be directed first against the underside of the leaves, beginning with the lowest branches and spraying upward. Most of the larvæ are feeding on the under surface of the leaves, and spraying the upper surface first would serve to knock the larvæ from the trees without their coming into contact with the spray. Angle nozzles of the type shown in figure 15, giving coarse, penetrating spray, should be used for all applications.

### MATERIALS TO USE.

The combination of 3 per cent homemade distillate-oil emulsion, made from raw distillate, 32° to 34° Baumé, and the nicotine solutions,

*a* *b*

FIG. 13.—*a*, French prune buds; *b*, Imperial prune buds; showing stage of earliest buds at time of first application against thrips. (Original.)

is given preference over all other sprays used so far. To dilute, measure out 5½ gallons of the stock emulsion for each 100-gallon spray tank, or 11 gallons for a 200-gallon tank; start the engine; pour the stock emulsion into the spray tank, and while the agitator is running, add the water to fill up the tank, putting in the strong nicotine solution last and after the stock emulsion has been diluted. For spraying in the interior counties add to this dilute oil-emulsion

commercial tobacco extract No. 1, which is a dark, almost viscous liquid containing 2.75 per cent nicotine, at the rate of 1 to 75; or tobacco extract No. 2, which is a light-colored liquid containing 40 per cent of almost nonvolatile nicotine at the rate of 1 to 1,500, or a fraction more than a pint to a 200-gallon tank. This form of the nicotine has been highly efficient and will in all probability be more satisfactory than the former. By reason of its greater concentration the handling and transportation charges will be much less; also, the nicotine contained in this preparation is much less volatile, thus allowing the use of a smaller amount of actual nicotine in the dilution, as it remains an active killing agent for a longer time on the trees.

FIG. 14.—Buds of Black Tartarian cherry at time of first application against thrips. About one-half natural size. (Original.)

In Santa Clara County greater dilutions than these have been found to be satisfactory, due most likely to different climatic conditions, evaporation there being much less at this time than in the interior counties where the atmosphere is drier. Growers in the Santa Clara Valley are advised to use the 3 per cent distillate-oil emulsion, with tobacco extract No. 1 added at the rate of 1 to 100 or tobacco extract No. 2 at the rate of 1 to 2,000. These recommendations hold for all thrips sprayings, for both adults and larvæ and on all varieties of deciduous fruits attacked by the pear thrips. No orchards should be sprayed, however, when the trees are in full bloom. All spraying for adults should be done before the blossoms appear and spraying for larvæ after a large proportion of the petals have fallen.

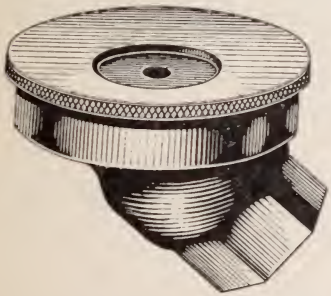


FIG. 15.—Angle nozzle of the large chamber type used in spraying experiments. (Original.)

In the prune orchards of Santa Clara Valley deep fall plowing and cross-plowing has proved a valuable and profitable aid in controlling the thrips. Those who can do so are strongly advised to irrigate their orchards in September or October, and when the soil is in proper condition plow with disk plows to a depth of 7 or

8 inches and harrow, then cross plow 8 to 9 inches deep and harrow again. All plowing should be done during the months of October and November. During this season the thrips are passing through the tender pupal stage and are more easily killed by mechanical means than at any other season of the year.

Plowing has not proved satisfactory as even a partial means of controlling the thrips in the pear orchards of the interior counties. This is due, perhaps, to several conditions, one of which is the different type of soil, and another, the fact that the area of soil infested with thrips around pear trees is very much less than around prune trees, the branches of which spread farther, covering a greater surface of ground. The larvæ in leaving the trees fall to the ground directly from the foliage and young fruit, rather than crawl down the trunks of the trees; hence in a prune orchard they are more widely distributed throughout the soil between the trees and can be reached by the plows, while in a pear orchard most of the larvæ in the ground are close around the base of the trees.

## SUMMARY.

The pear thrips can be controlled by thorough spraying on any variety of the deciduous fruits grown in the infested areas of California.

The sprayings necessary to control the thrips are expensive, but the outlay of money and labor gives large returns. Many experiments in spraying have given net returns of from $100 to $600 per acre more than was secured from adjoining untreated areas.

The thrips work rapidly and may destroy all prospects of a crop in less than a week's time. Spraying, to be successful, must be done thoroughly and at the time to kill the thrips before the fruit buds have been destroyed.

Those who can do so successfully are advised to irrigate and plow in the fall. This is to be followed by thorough spraying the following spring.

When the thrips begin to appear on the trees in numbers, spraying should be done thoroughly, using high pressure, holding nozzles close to buds, and *directing the spray directly into the ends of the buds, and not against the sides.*

Growers should not attempt to spray too many trees with one machine. More profitable returns will be gained by spraying half of the orchard thoroughly and at the proper times than by spraying all the orchard poorly one time. Results of the work in 1909 and 1910 show conclusively that one application is not sufficient when the thrips are abundant.

O